Characterization of Fraglight Non-Woven Felt and

Simulation of FSP's Impact in It

Sidney Chocron
(Principal Investigator)

Antonio F. Pintor

Francisco Gálvez

Prepared for
United States Army
European Research Office of the U.S. Army
London, England

Contract no.: N68171-00-M-5983
R&D 8927-AN-01

Contractor:
Fundación Agustín de Betancourt
E.T.S.I. Caminos Canales y Puertos
Universidad Politécnica de Madrid
Madrid 28040 - SPAIN

2nd Interim Report 12 DEC 2000-13 March 2001

The Research reported in this document has been made possible through the support and sponsorship of the U.S. Government through its European Research Office of the US Army. This report is intended only for the internal management use of the Contractor and U.S. Government

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	15 March 2001	[illegible] 2000 – 12 March 2001

4. TITLE AND SUBTITLE
Characterization of Fraglight Non-Woven Felt and Simulation of FSP's Impact in It

5. FUNDING NUMBERS
N68171-00-M-5983

6. AUTHOR(S)
Sidney Chocron (Principal Investigator)
Antonio Pintor
Francisco Gálvez

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Fundación Agustín de Betancourt
E.T.S.I. Caminos Canales y Puertos
Universidad Politécnica de Madrid
Madrid 28040 - SPAIN

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
USARDSG-UK
EDISON HOUSE 223 OLD MARYLEBONE ROAD
LONDON NW1 5TH

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The objective of this project is to gain insight in the behavior of the non-woven felt commercially known as Dyneema Fraglight. The following activities were performed during the period covered by this report: 1) Tests at different temperatures and orientations. 2) Search of characteristic length of fiber and fabric. 3) High strain rate specimen designed and difficulties in Hopkinson bar testing. 4) Calibration and set-up of the image system that will record the history of the impact of FSPs into the Dyneema Fraglight. The main conclusions are 1) The characteristic length of the fiber is 4-5 cm. 2) Heating the fabric at 100 C weakens it by 40% .3) Longitudinal and 45 degrees specimen are much weaker than transverse specimens. 4) Hopkinson bar tests will be difficult since specimens strain too much before failing. 5) Preliminary shooting tests with high speed photography indicate it is possible to obtain longitudinal and transverse wave speed in the fabric.

14. SUBJECT TERMS
Polyethylene, non-woven felt, mechanical characterization, body armor, high strain rate, Dyneema Fraglight, gripping system, fabric target.

15. NUMBER OF PAGES
9

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

1. Scientific Work Done During Reported Period

The objective of this project is to gain insight in the behavior of the non-woven felt commercially known as Dyneema Fraglight and its outstanding performance to stop fragments. During this second period most of the material mechanical characterization work was completed:

1) Search of a characteristic length of the fiber
2) Dependence of properties on the direction of application of load
3) Dependence of properties on temperature
4) Dependence on strain rate
5) Gas gun and high speed cameras calibration and set-up

1.1 Search of a characteristic length of the fiber.

The Fraglight is a non-woven felt made of short fibers. This microstructure is the origin for a strong dependence of the properties on the size of the specimen tested. The authors think it is interesting to study this size effect that should be taken into account when dealing with analytical or numerical models of the material in the second part of this project.

The tests performed consisted in tensile tests of specimens where the length was a parameter varying from 10 to 100 mm, while the width was kept constant (100 mm). An example of these tests is shown in Figure 1.

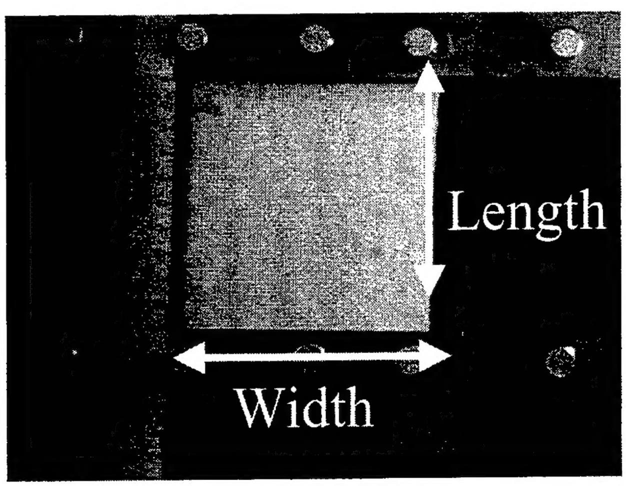

Figure 1: Specimen gripped, ready to be tested in tension

The specimens were always tested in the transverse configuration, meaning that its length direction was transverse to the roll where the specimen was cut from. The first interim report explained that the transverse direction is much more resistant since most of the fibers are aligned in that direction.

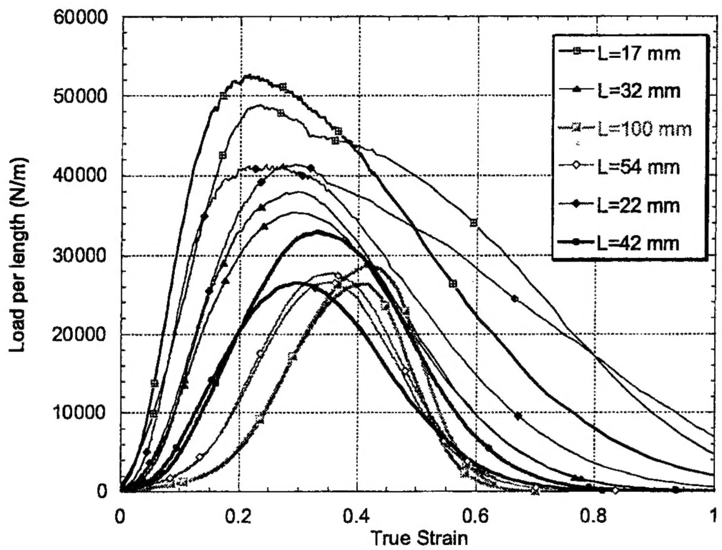

Figure 2: Summary of the size effect tensile tests

Specimens of nominal lengths of 10, 20, 30, 40, 50, 60 and 100 mm were tested obtaining the results of Figure 2. At least three tests per specimen were performed, although not all of them are plot in the figure. As it was expected short specimens are much stronger than long specimens, but specimens longer than 40 mm have similar properties. The authors do not think that the specimens of 100 mm length have a higher strain to failure, but rather that it is a two dimensional effect: the specimen's width decreases during the test much more in long than in short specimens.

1.2 Dependence of properties on the direction of application of load

As was previously reported the properties of Dyneema Fraglight are very different for longitudinal and transverse specimen cuts, implying that there is a direction where most of the fibers are aligned. That direction is the transverse direction of the roll provided by Dyneema.

Figure 3 shows the tests performed on transverse, longitudinal and 45 degrees rotation specimens. All specimens were squares of 100 mm x 100 mm. Longitudinal specimens could not be broken during the test because the stroke of the machine used was not long enough. Nevertheless the plot indicates that the specimen was close to failure at a 150% strain. At 45 degrees the strength is also very low, around one-third the value of the transverse specimens.

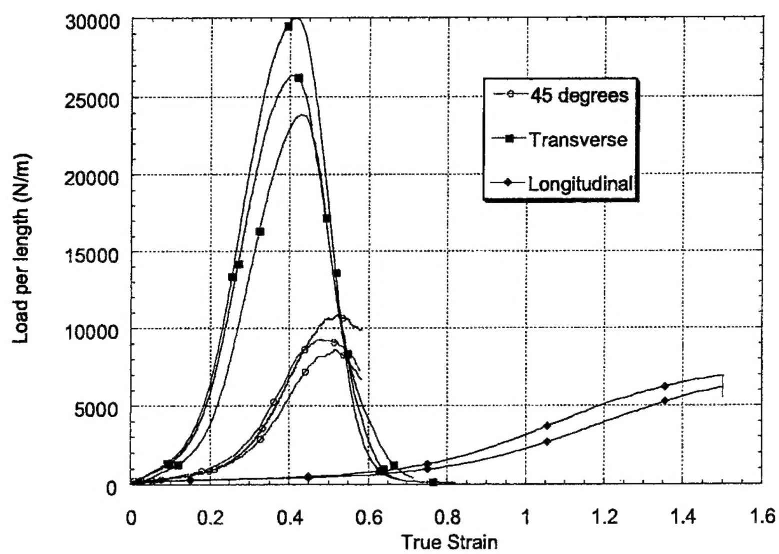

Figure 3: Summary of the direction dependence study

1.3 Dependence of properties on temperature

Specimens of size 100 mm x 100 mm were tested at room temperature (20 C), 50 C and 100 C. Dyneema Fraglight is made of polyethylene fibers, so the temperature was expected to weaken considerably the felt. Temperature is another factor to be taken into account when modeling impact on Fraglight, since probably some melting of the fiber takes place during penetration. All the specimens were kept at the temperature of the test during 30 minutes prior to the beginning of the tensile test.

Figure 4 clearly demonstrates that the felt is weakened (20 %) at moderate temperatures like 50C. At 100C both the strength and the strain to failure reduce significantly: the strength by 40% and the strain by 60%. This would probably mean that the performance at high temperature of a Fraglight armor is very poor.

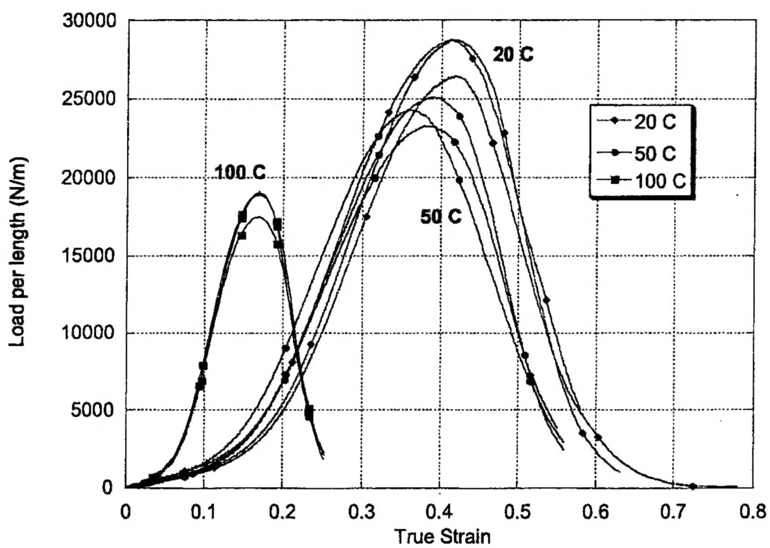

Figure 4: Temperature study on Dyneema Fraglight

1.4 Dependence of properties on strain rate.

Interim report number 1 already showed that strength and strain to failure at rates of $1 s^{-1}$ and 10^{-3} s^{-1} are very similar. Hopkinson bar tests would allow to reach 10^{3} s^{-1} strain rates, but unfortunately the same specimen shape cannot be used. The Hopkinson bar of our laboratory is 22 mm diameter, so the limit in width for the specimen is in principle also 22 mm. Since this width does not seem to be large enough to get real stress-strain curves a "tubular" specimen was designed. The tubular specimen consisted of a plane 100 mm x 100 mm specimen rolled like a cigar.

Firstly static tests of tubular specimens were performed to check that their properties were similar to the regular specimens (squares 100 mm x 100 mm). Figure 5 shows that unfortunately this is not the case. When the tubular specimen is tested its diameter reduces creating high compression on the fibers inside, making difficult the slippage and hence increasing the strength. Comparing with Figure 2, the strength is doubled.

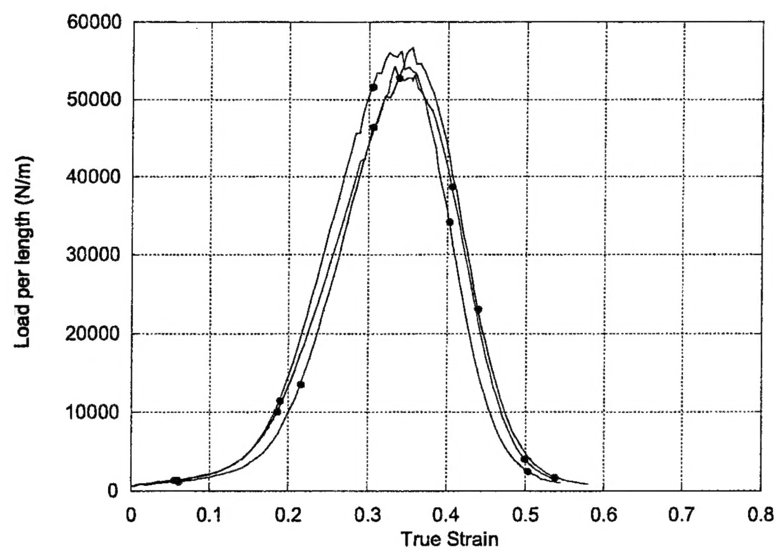

Figure 5: Results with tubular specimens

This is not the only problem to be solved in Hopkinson bar tests. The longer tensile pulse that can be obtained in the Hopkinson bar is of 200 μs, which means maximum displacement of the bar of 4 mm during the test (the bar moves at 20 m/s). The strain to

failure of Fraglight is very high, around 30 to 40%. For a 5 cm specimen a displacement to failure of 2 or 3 cm is needed to break the specimen. The Hopkinson bar of the department is limited in that sense and measures are being taken to overcome this difficult problem.

1.5 Gas gun and high speed cameras set up.

During this reported period the gas gun and high speed photography cameras have been checked and the system is now calibrated and ready to be able to track the strain in the fabrics and measure the residual velocity in the tests.

Preliminary test seem to indicate that it will be possible to determine transverse and longitudinal wave speeds in the fabric.

2. Future Work for Interim Report no. 3

1) Out of plane tests of the fabric
2) Hopkinson bar tests
3) Image tracking of the back of the fabric when shot with FSPs
4) Residual vs. striking velocity curves for different configurations

3. Significant Administrative Actions for this Period

No significant action to be mentioned.